

Acousto-optical coupled-wave theory with highly confined acoustic guided modes

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The interaction of light and acoustic waves has led to a number of applications in optical signal processing. The recent interest in combined phononic and photonic (phoxonic) band gap materials has raised the problem of 2-D guided-wave interactions with highly confined modes. This is for instance the case of a holey fiber exhibiting a band gap for guided acoustic waves, thus allowing the simultaneous propagation of optical and acoustic waves in a micron-size core. However, in the literature, the acoustic field is generally described as if it were a plane wave. Such an approach implicitly assumes that the lateral dimensions are large compared to the acoustic wavelength, which is obviously not valid in the case investigated here.

In this work, we formulate a coupled-wave theory describing the guided acousto-optical interaction with the actual mode shapes explicitly taken into account. It will be argued that the coupled-wave equations assume slightly different forms depending on whether the electric field \mathbf{E} or the displacement field \mathbf{D} of the initial unperturbed optical modes is chosen. Specifically, although both formulations can be cast in the form of vectorial first-order differential equations, additional coupling terms arise in the \mathbf{D} -formulation that are dependent on the transverse gradient of the strain field. The case of honeycomb photonic crystal fibers will be considered to give an insight in the enhancement of the elasto-optical coupling that can be achieved by confinement.